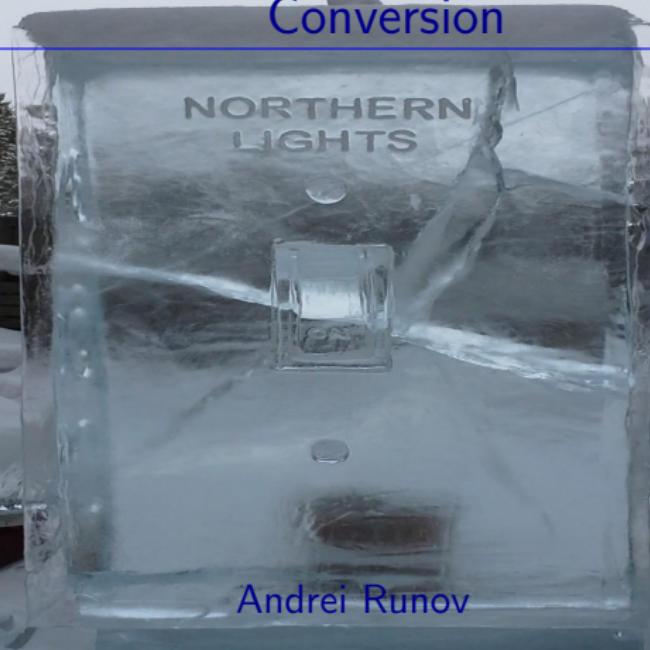




# A Role of Transient Dipolarizations in the Magnetotail Energy Conversion

UCLA

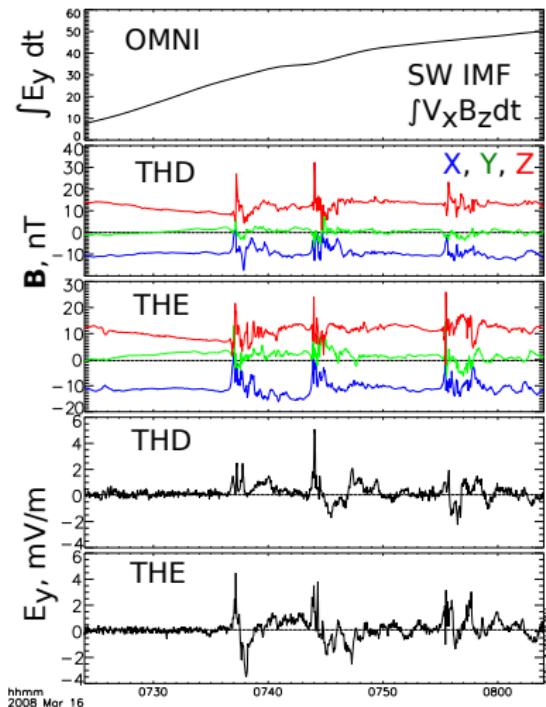


Andrei Runov

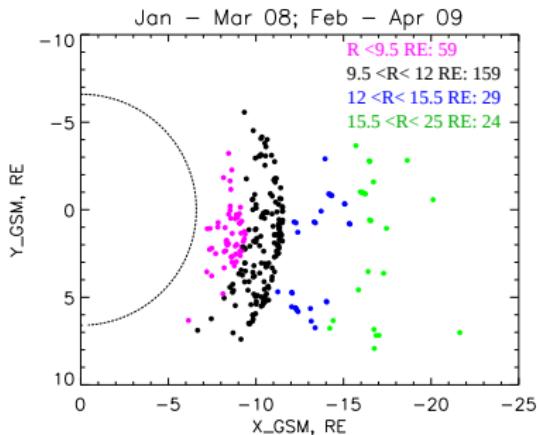
Thanks to V. Angelopoulos and THEMIS team  
A. Artemyev, J. Birn, C. Gabrielse, M. Hesse, J. Liu, D.L. Turner, X.Z. Zhou  
&  
NASA contract NAS5-02099, grants NNX13AF81G, and NNX16AF84G

# Transient Dipolarizations and Flux Transport: an Example of THEMIS Observations

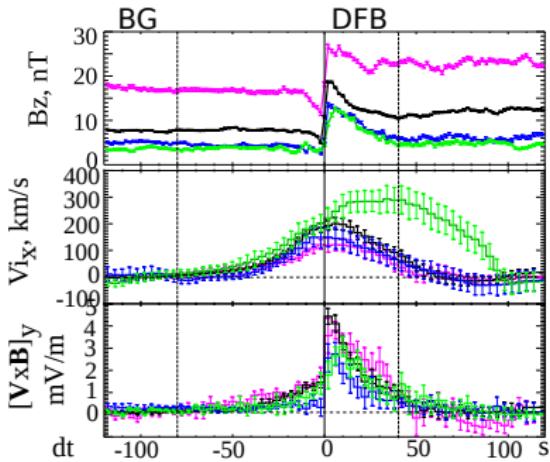
- Arbitrary chosen example
- OMNI Integrated Electric Field
- THEMIS
- $\mathbf{D}[-10.5, 3.5]$  and  $\mathbf{E}[-10.3, 4.5] R_E$ :
  - ▶  $B_x$  (blue);  $B_y$  (green);  $B_z$  (red)
  - ▶  $E_y = -[\mathbf{V} \times \mathbf{B}]_y$
- **Transient response:**  
Pulses of magnetic flux transport  
with a characteristic time of 30 -  
100 s.
- Rapid Flux Transport (RTF) events  
(Schoedel et al., 2001)
- Dipolarizing Flux Bundles (DFBs)  
(J. Liu et al., 2013)
- Typical behavior, see, e.g.,  
Angelopoulos et al., Science 2013  
for similar example.



# RFT/DFB THEMIS Statistics



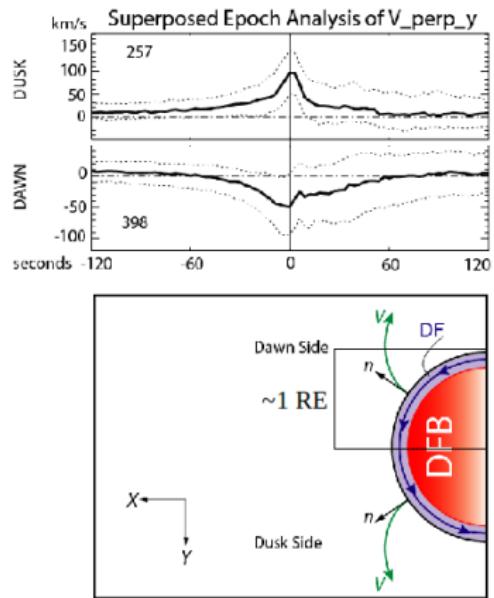
- $dB_z/dt > 0.5$  nT/s  
(J.Liu et al., 2013)
- $N_{dfb} < N_{bg}$ :  $N_{dfb}/N_{bg} < 0.9$
- 271 event at  $7 < R < 25$  RE



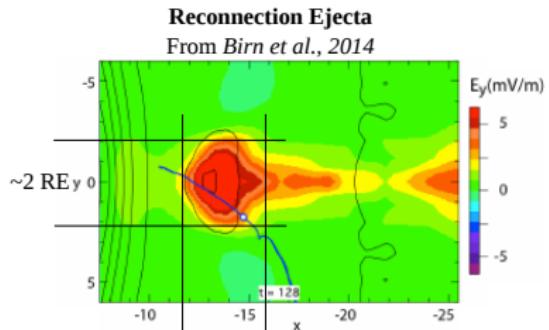
After Runov et al. (2015)

- Transient dipolarization at  $R > 12 R_E$ , more sustained at  $R < 12 R_E$ ;
- Flow braking;  $V_x$  maximum behind the front at  $R > 15 R_E$
- Flux transfer ( $E_y$ ) pulse duration  $\sim 40$  s  $\Rightarrow$   $\sim 0.5$  to  $\sim 2 R_E$  in length.

# RTF/DFB Scales



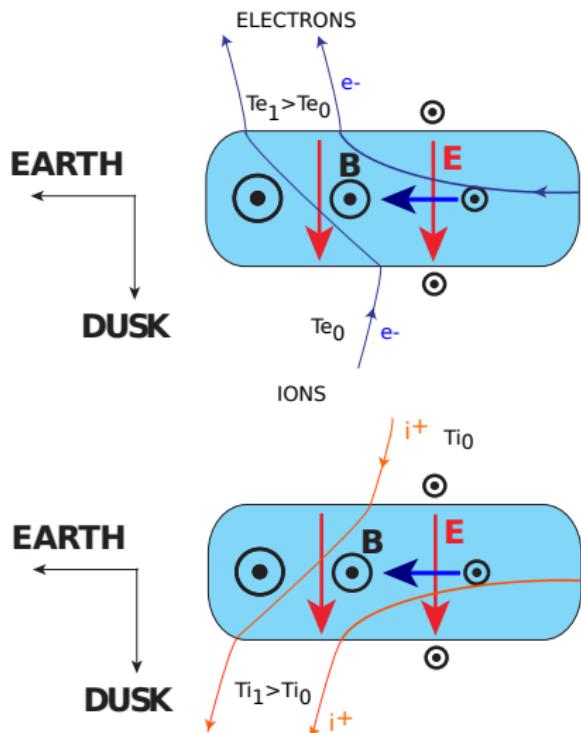
After J. Liu et al. (2013)



Birn et al., 2014: MHD with  $\eta = \eta_0 / \cosh^2(\frac{x}{L_x}, \frac{y}{L_y}, \frac{z}{L_z})$ ,  $L_y = 8$

- Spatially localized electric field (magnetic flux transport) enhancement;
- Scale:  $\sim 2 \times 2 R_E \sim 30 \times 30 c/\omega_{pi}$
- **Why do we care?**

# Conceptual Cartoons

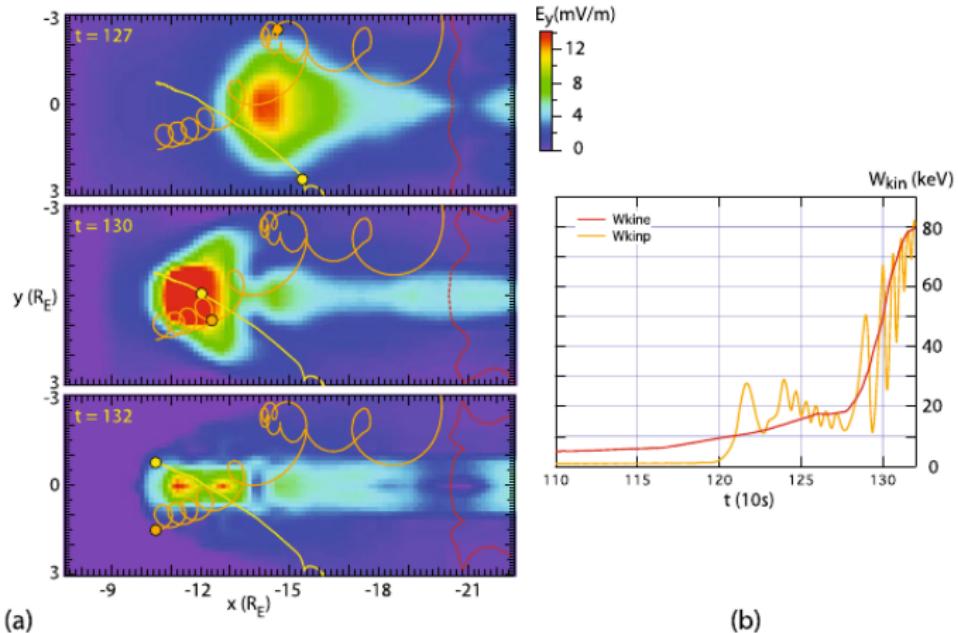


- Contracting dipolarized flux tube;
- $B_z$  enhancement within an area **A**: a localized enhancement in the magnetic flux through the equatorial plane  
 $\Phi = \int_A \mathbf{B} \cdot d\mathbf{A} \sim 10 \text{ nT} \cdot 10^8 \text{ km}^2 \sim 10^{11} \text{ Wb}$
- **E** pulse in the stationary FOR  
⇒ Interaction with ambient particles: energization  
 $E_y \sim 1 - 5 \text{ mV/m}; \Delta Y \sim 10^7 \text{ m}$   
⇒  $\Delta U = E_y \cdot \Delta Y \sim 10 - 50 \text{ keV}$
- **Continuous EM energy conversion into thermal energy of the ambient plasma**

$$\delta E \sim \frac{1}{\mu_0} E_y B_z \sim 10^9 - 10^{10} \text{ J/R}_E^2/\text{s};$$
$$\tau \sim 100 \text{ s} \Rightarrow 10 - 100 \text{ GJ/R}_E^2$$

Birn et al. (2012); Gabrielse et al. (2012);  
Runov et al. (2013)

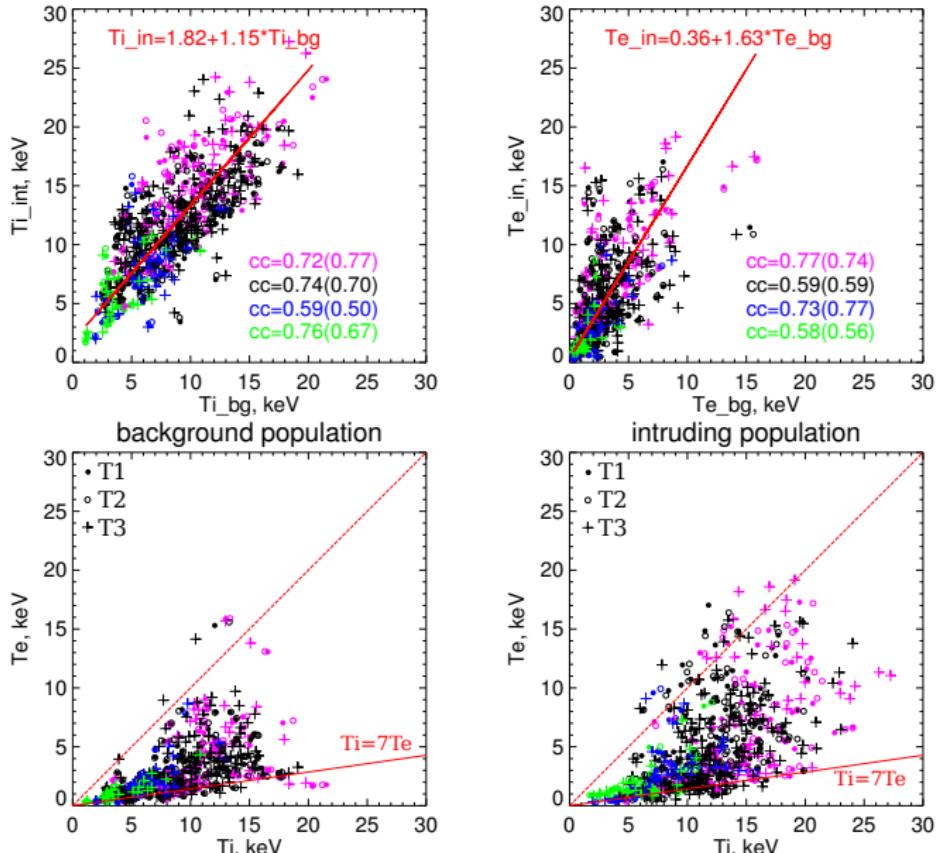
# Test Particle Simulations



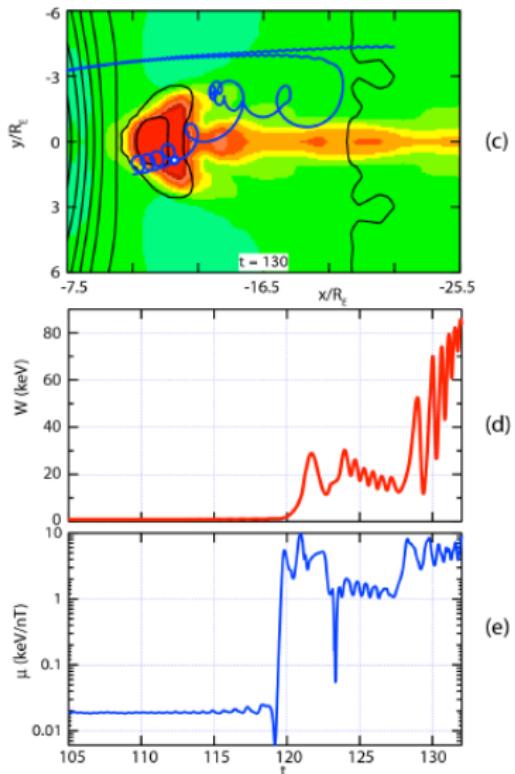
From Birn et al. SSR, 2012

- Correlation between background and DFB ion and electron temperatures
- Hotter electrons on the dawn; hotter ions on the dusk side;
- Do we observe this?

# $T_{in}/T_{bg}$ Correlation; $T_e/T_i$ Ratio (*Runov et al., 2015*)



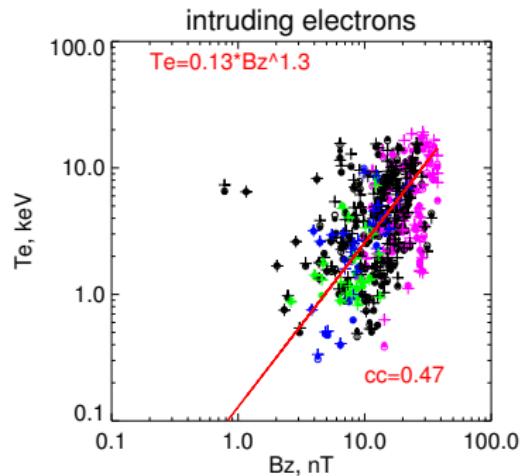
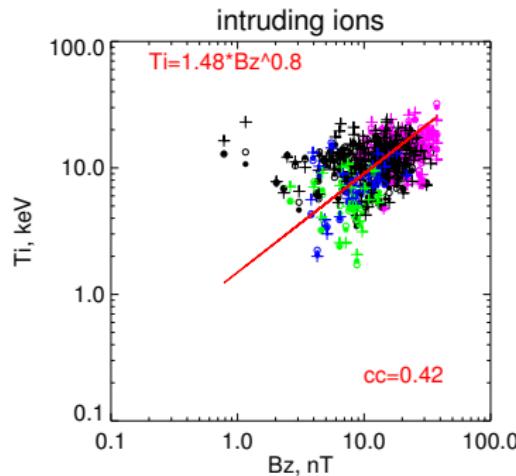
# Test Particle Simulations: Ions



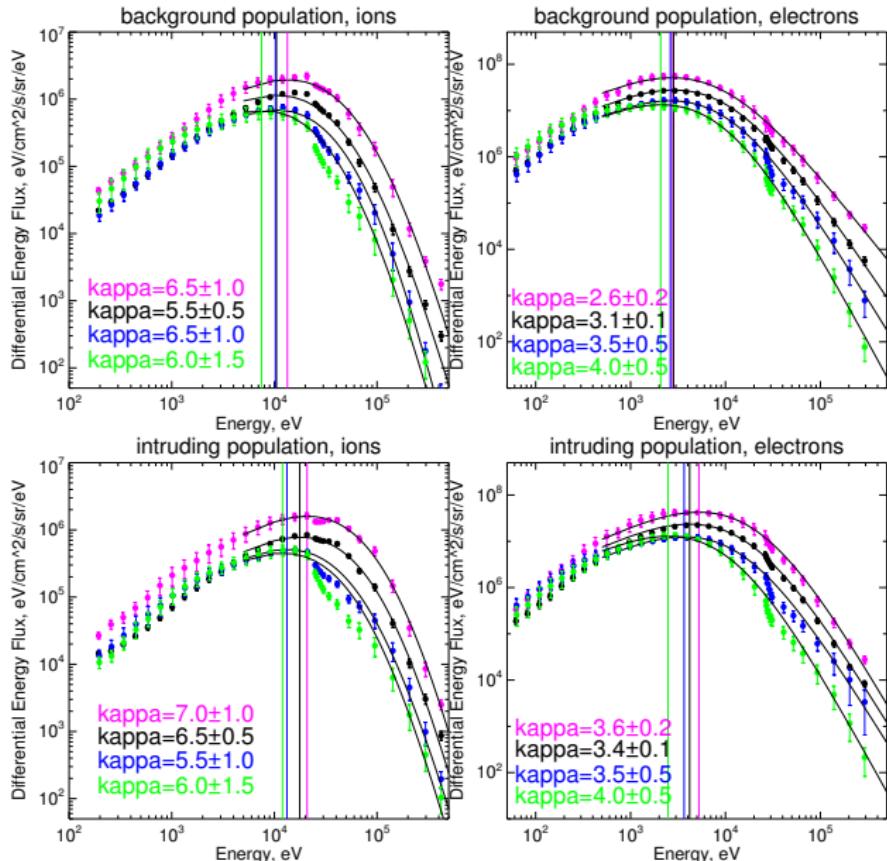
From Birn et al. JGR, 2015

# $T_{i,e}(B_z)$ Correlation and Linear Regression

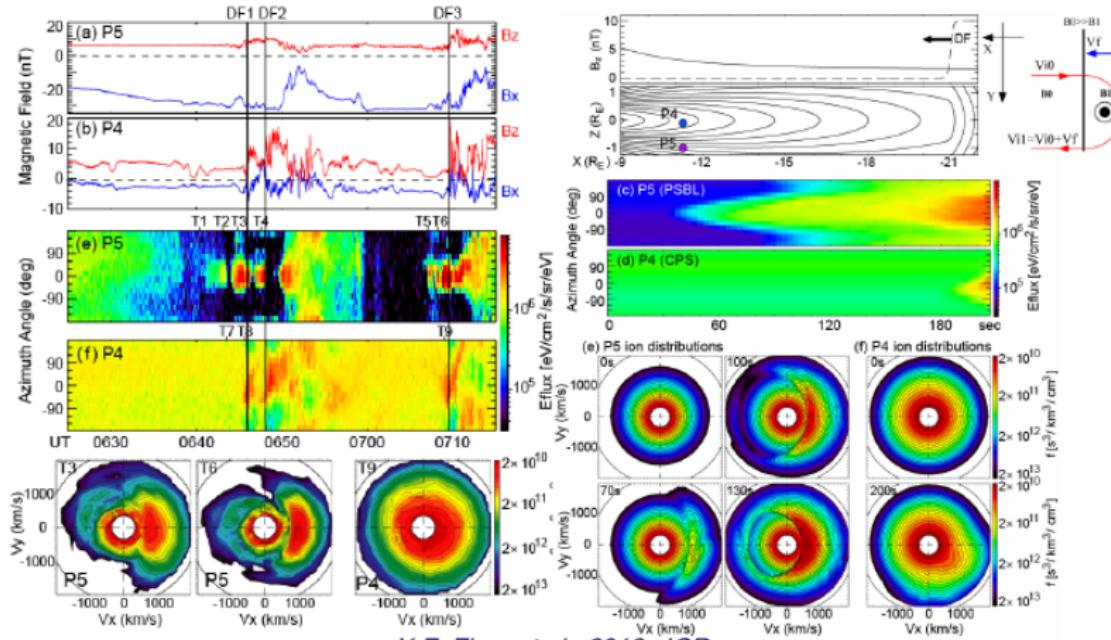
- $\mu_{i,e} \approx \text{constant}$  (e.g., Birn et al., 2015)  $\Rightarrow T_{i,e} \propto B_z^\alpha$ ,  $\alpha \sim 1$



# Ion and Electron Spectra: $J(E) = n \left( \frac{E}{m^2} \right) \left( \frac{m}{\pi \kappa E_0} \right)^{3/2} \frac{\Gamma(\kappa+1)}{\Gamma(\kappa-1/2)} \left( 1 + \frac{E}{\kappa E_0} \right)^{-\kappa-1}$

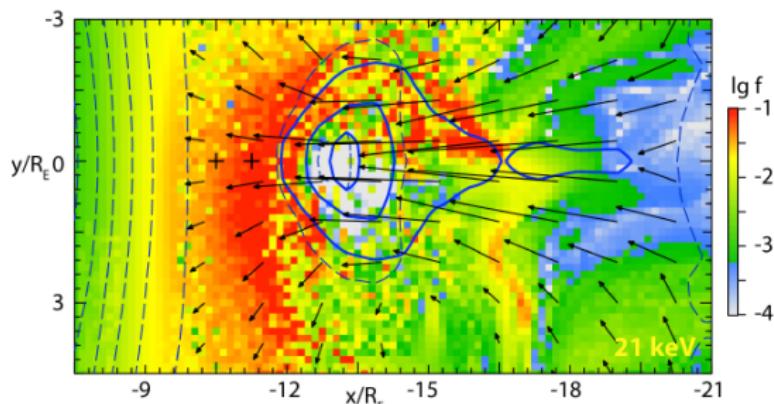


# Shabansky-type Interaction with Ambient Ions



X-Z. Zhou et al., 2012, JGR

# Precursor Ion Flux in Test-Particle Simulations

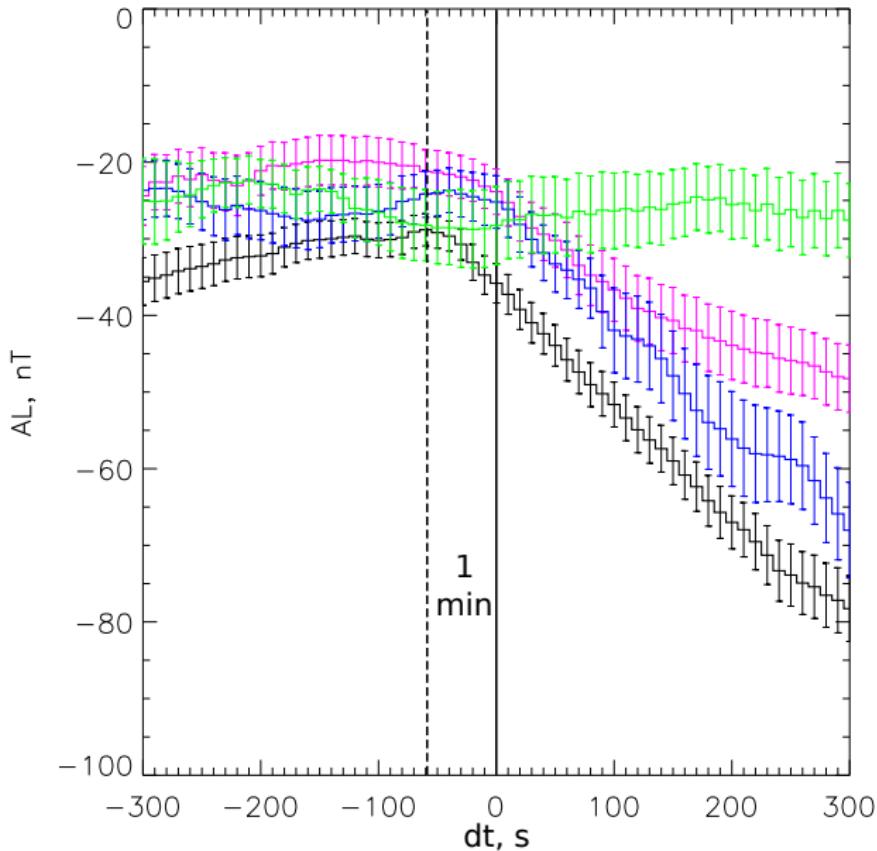


From *Birn et al., (2015)*

see also *Artemyev et al., (2015)*

- FBs convert EM energy into thermal and mechanical energy of ambient plasma by
  - ▶ pick up ambient particles via  $\mathbf{E} = \mathbf{V} \times \mathbf{B}$ ;
  - ▶ Shabansky-type ion reflection on the FB (dipolarization/jet) front.

# Are FB Associated With Substorm (AL) Onset?

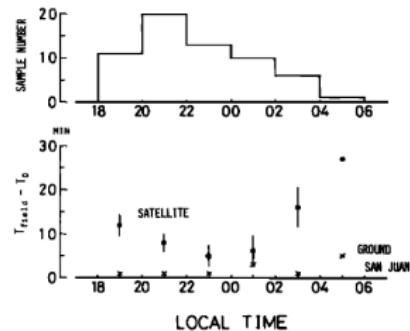


## Summary

- Earthward moving transient dipolarizations (RFT/DFB) serve as **energy converters** that convert the electromagnetic energy into the thermal and mechanical energy of ambient particles;
- They may be thought as **elementary building blocks** (after *Sergeev et al. 1996*) of magnetotail activity;
- 3-D effect.

# Open Questions

- FBs at  $R < 15 R_E$  are typically observed within  $dt \leq 1$  min of AL onset
  - ▶ What is the association between the flow bursts and (global) **substorm** current wedge development?
  - ▶ How the magnetotail transients are integrated into the 10s m-long global (a few hrs of MLT) dipolarization observed at GEO?
  - ▶ Is there any physical connection between transient trans-geosynchronous 'injections' ( $\sim 10 - 100$  s increase in supra-thermal particle fluxes) and sustained injections and the **injection boundary** observed at GEO?



Nagai, (1982)